Grinding Process Modeling and Cycle Design

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PROJECT OBJECTIVES

- Develop a grinding model to predict the main process outputs such as power, forces, and part surface roughness.

- Use the grinding model to find the optimal process settings to produce the desired part quality subject to machine capability constraints.

- Implement and test the final cycle design in a cylindrical grinding machine with an open architecture system.

MODEL 1 – THE GRINDING CHIP

The chip is idealized as a long slab with constant thickness , *h*, and a triangular cross section.

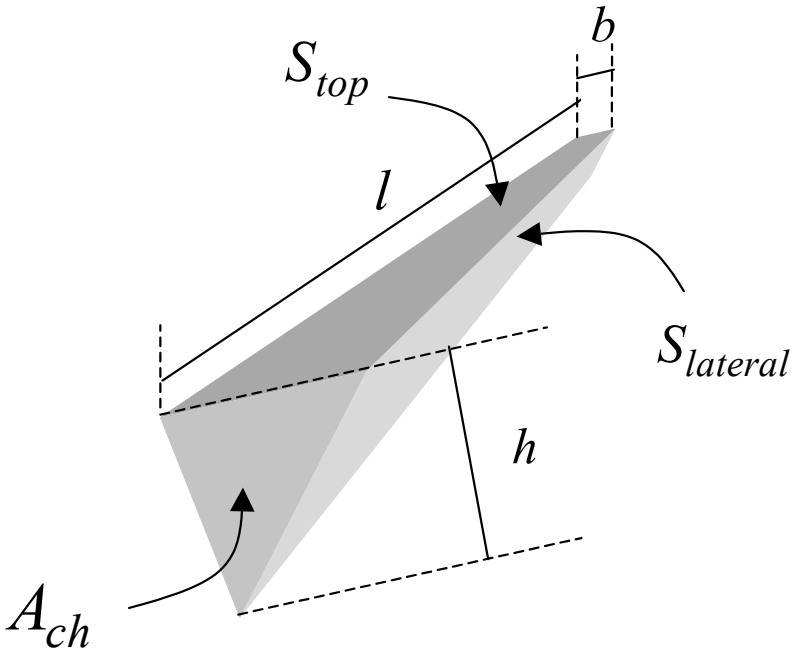

Figure 1. Idealized chip geometry

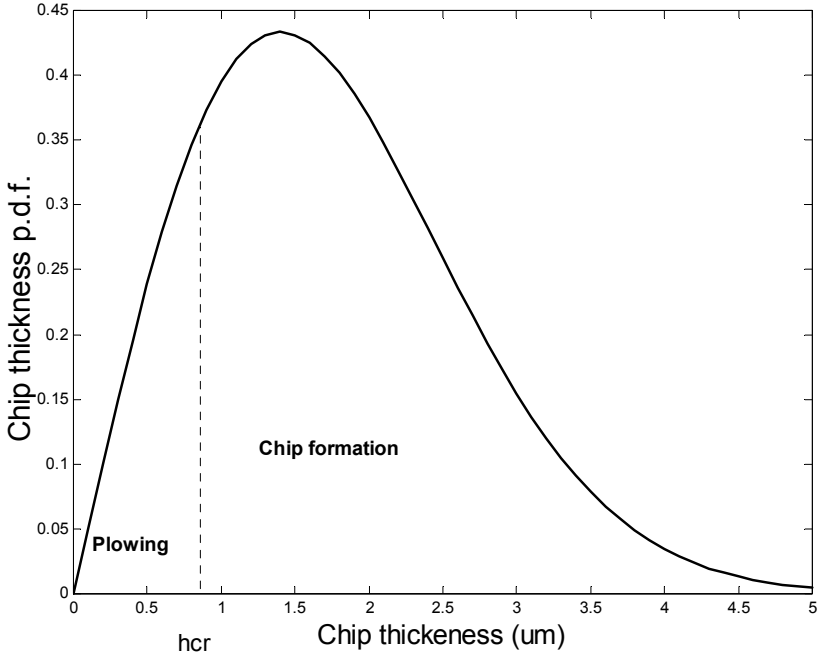

Figure 2. Probability density of function of the chip thickness

The chip thickness is assumed to take a Rayleigh probability density function

MODEL 2 – GRINDING WHEEL CHARACTERIZATION

- Print the wheel surface in a soft material
- 3-D surface topography scanning by Zygo
- Image processing to characterize: grit geometry and static cutting edge density
- Dynamic cutting edge calculation ⟷ Chip thickness model

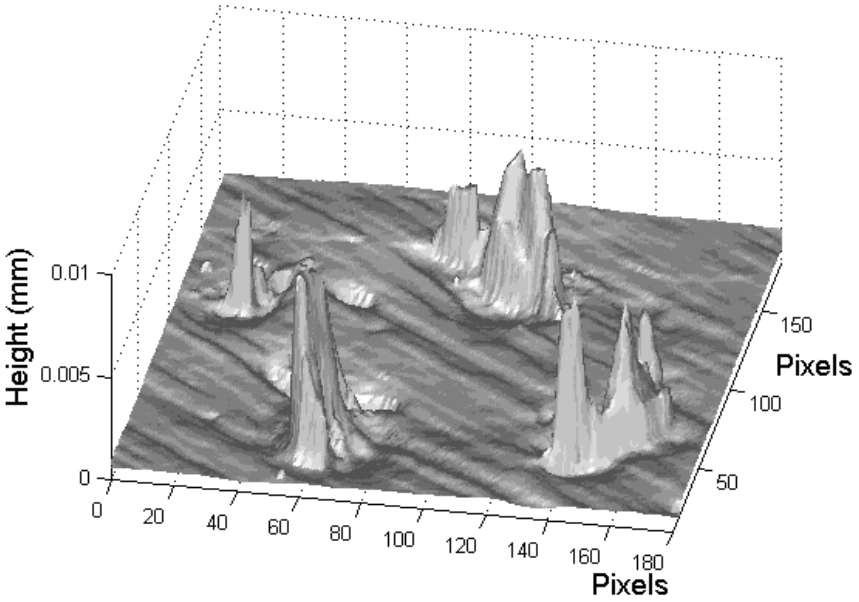

Figure 3. 3-D wheel topography

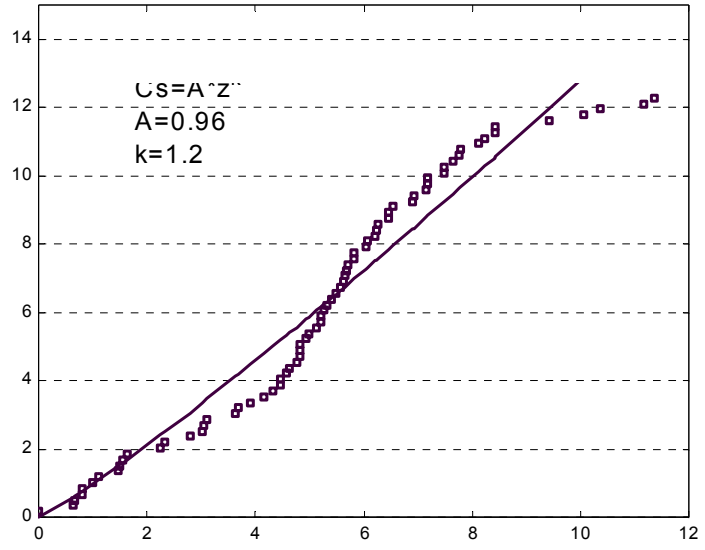

Figure 4. Static grain density

MODEL 3 – MAIN CONCEPT

The model is a closed-loop system by considering dynamic effects produced by the total normal force and the normal force per grain

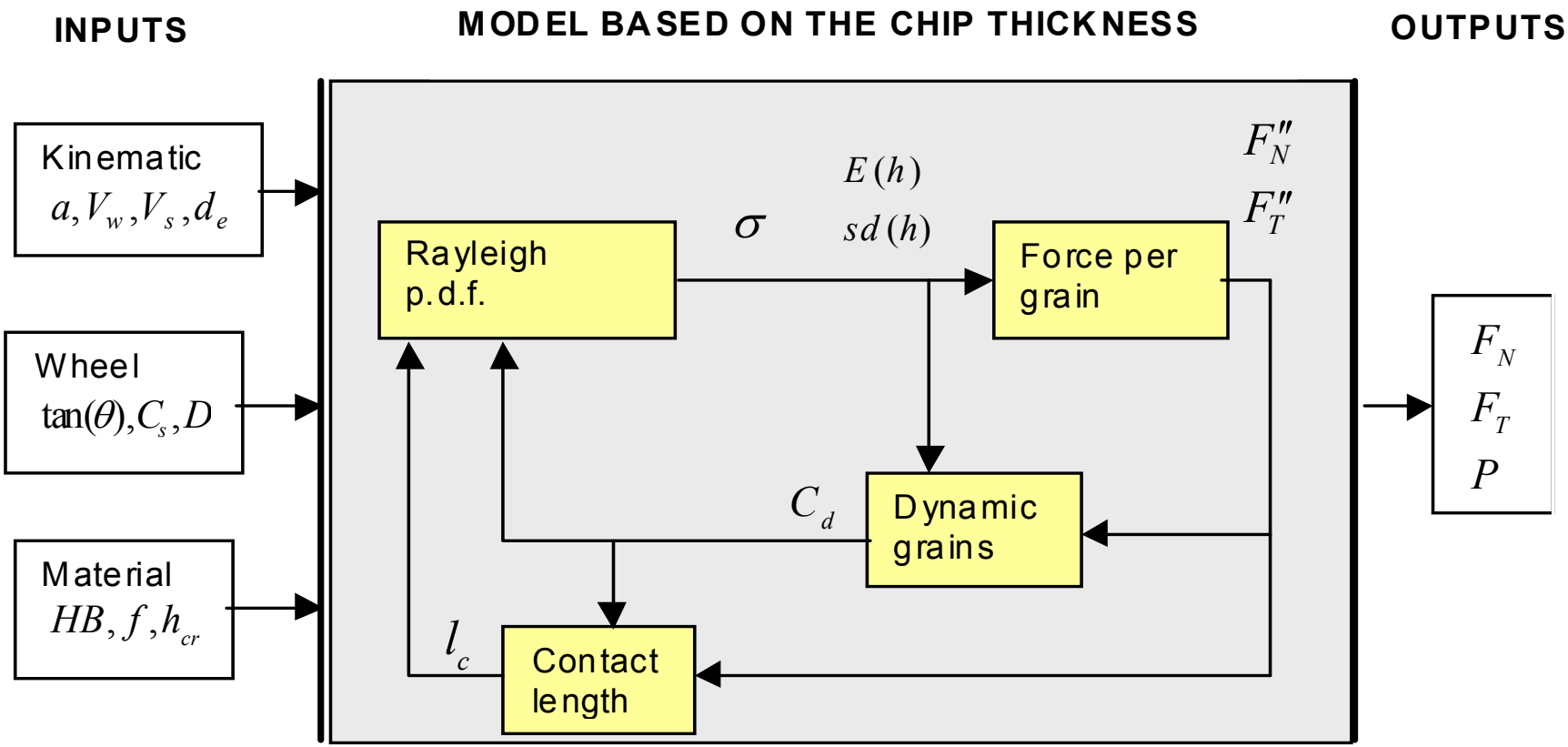

Figure 5. Block diagram to represent the grinding model

MODEL 4 – CALIBRATION AND VALIDATION

The model was calibrated and validated using the normal and tangential force in surface grinding and also using the grinding power in cylindrical grinding

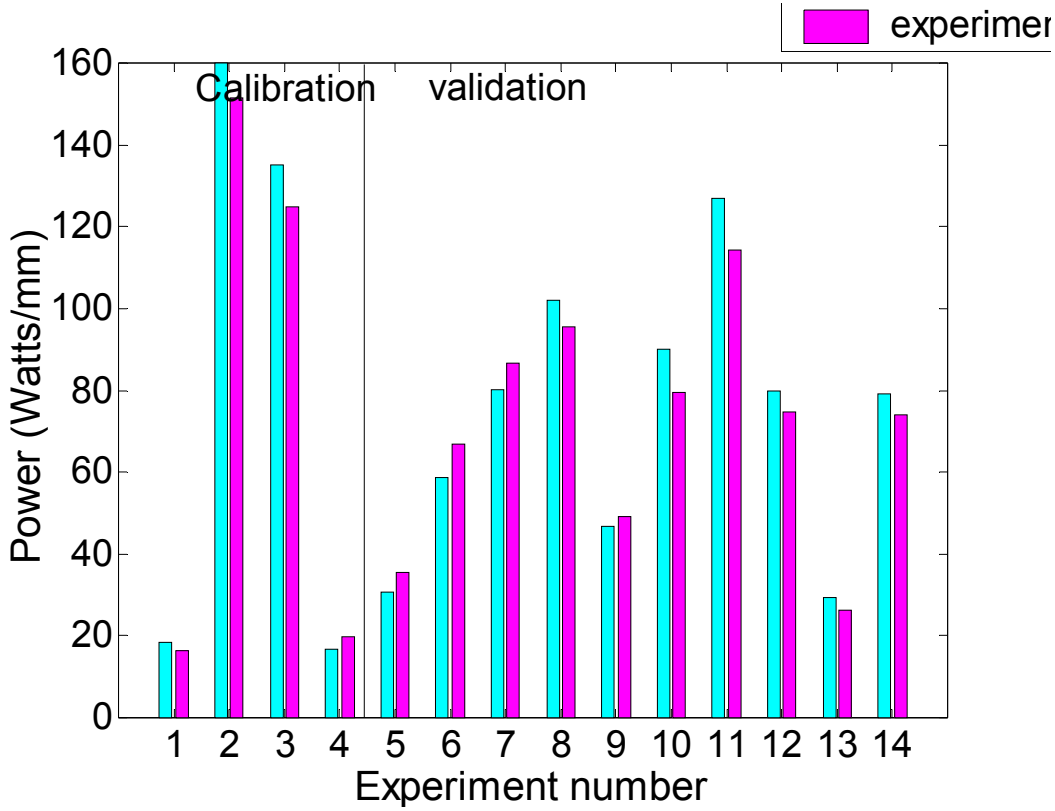

Figure 6. Model calibration and validation using the grinding power

MODEL 5 - SURFACE ROUGHNESS MODEL

The surface profile is generated by the grooves left by the grains on the part surface. The depth of the grooves is assumed to be equal to the chip thickness

By probabilistic analysis

$$E\left(R_a\right) = 0.37\,E\left(h\right)$$

Empirically adjusted as

$$E\left(R_a\right) = 0.32\,E\left(h\right)$$

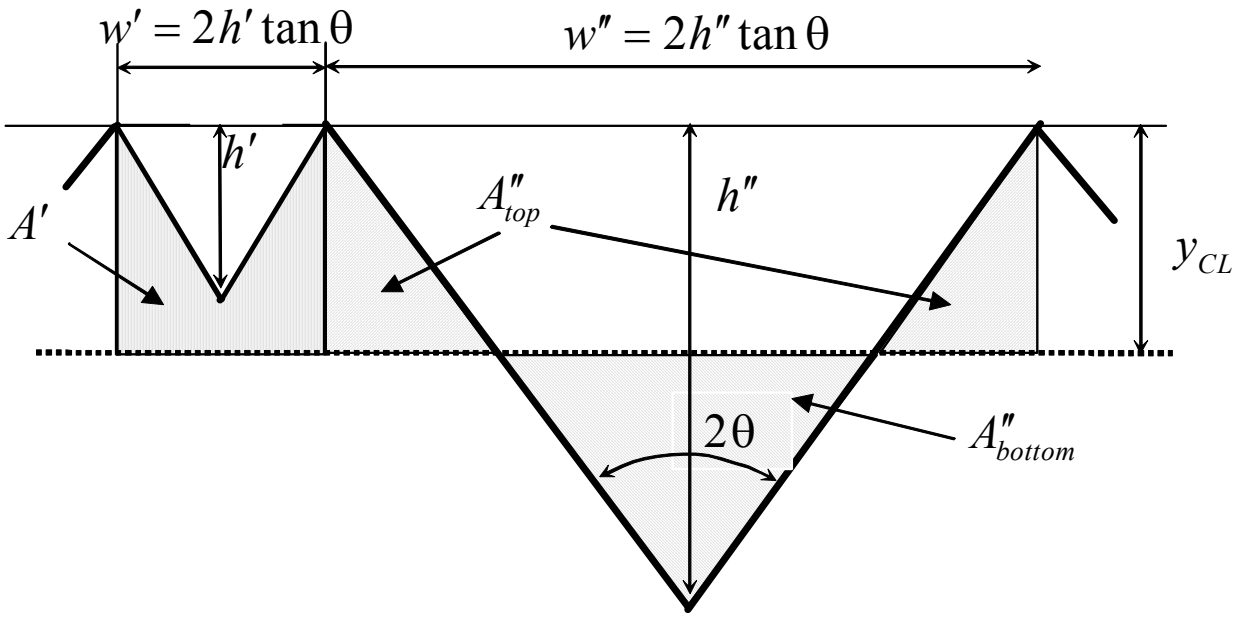

Figure 7. Ideal surface roughness profile

CYCLE DESIGN - CONTRAINTS

Stock removal: Machine capability and part surface burn → **Power control**

Final stage: Surface roughness and out-of-roundness → **Feed control**

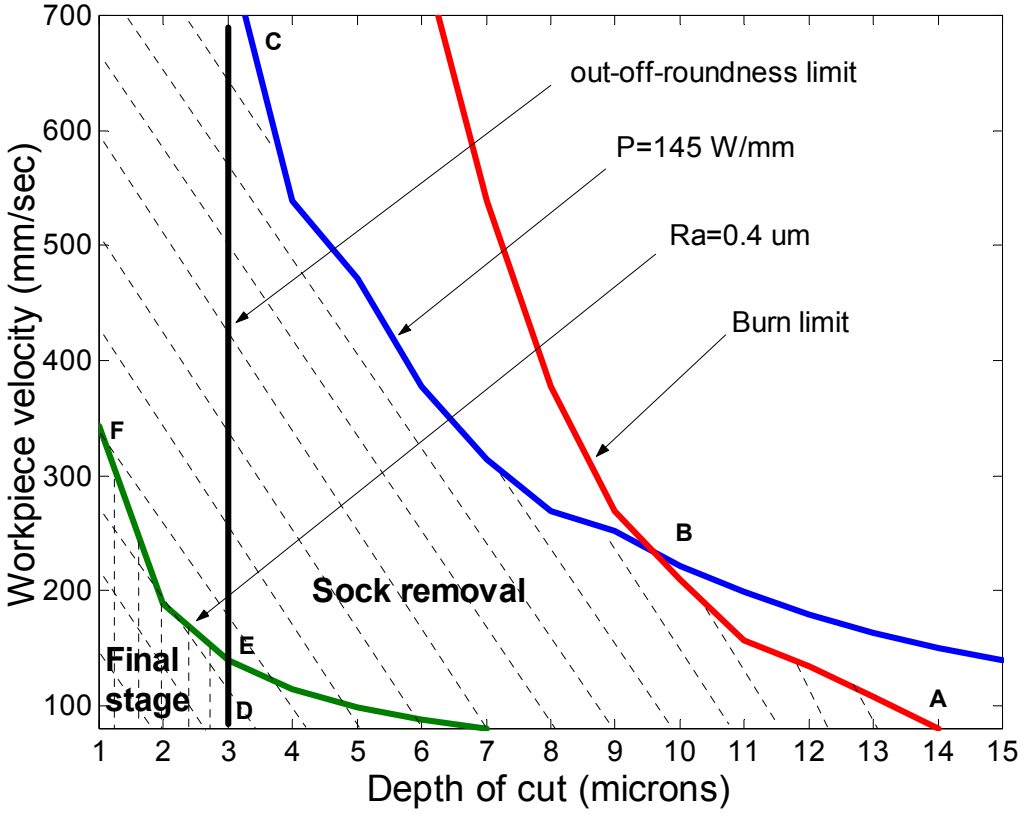

Figure 8. Constraints in the plane workpiece velocity vs. depth of cut

CYCLE IMPLEMENTATION

Material removed

First layer: power control

Second layer: feed control

Third layer: spark-out or remaining material

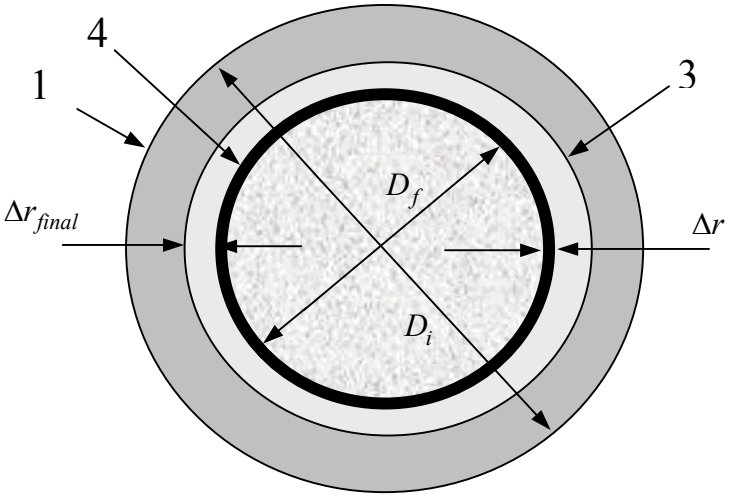

Figure 9. Workpiece cross section

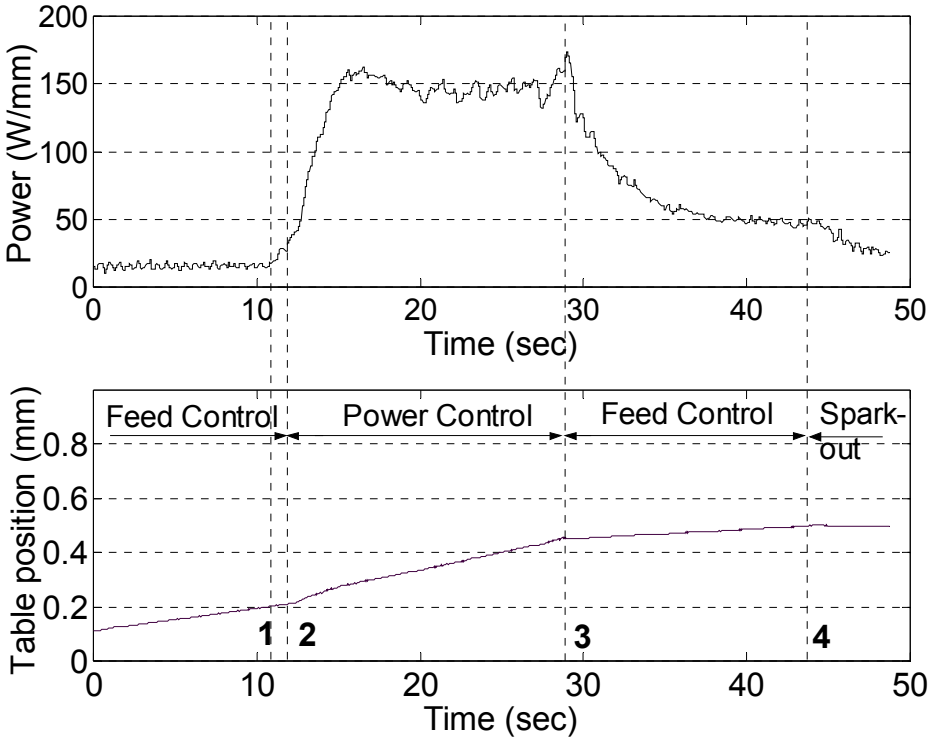

Figure 10. Power and infeed response

CONCLUSIONS

- Development of a grinding model based on the probabilistic nature of the grinding chip.

- Design of a grinding cycle based on the grinding model with the constraints of machine capabilities and part quality.

- Cycle implementation in an open architecture system